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HEAT TRANSFER ANALYSIS OF SECOND GRADE FLUID OVER A STRETCHING SHEET THROUGH POROUS MEDIUM UNDER THE INFLUENCE OF CHEMICAL REACTION PARAMETER

K. V. CHANDRA SEKHAR

Department of Mathematics, Koneru Lakshmaiah Education Foundation, Vaddeswaram ,
Guntur District, Andhra Pradesh, India

ABSTRACT

Evaluation has been done to study heat transfer of a second grade fluid through porous medium under the influence of chemical reaction parameter over a linear impermeable stretching sheet. Similarity transformations are being used to reduce the governing differential equations to ordinary ones which are solved numerically. Effects of different parameters were studied on the fluid flow. The results of stream and heat transfer were shown graphically.

KEYWORDS: Stretching Sheet, Porous Medium, Viscous Dissipation & Chemical Reaction Parameter

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Nomenclature

x	Directional coordinate of flow along the stretching sheet
y	Distance normal to the stretching sheet
u , v	Velocity componponents of x and y direction
A, D	Constants
c_P	Specific heat at constant pressure
k_0	Parameter of elasticity
k_1	Parameter of Second grade fluid
k_2	Parameter of Permeability
T_w	Temperature at wall
Pr	Prandtl number
T_∞	Temperature away from plate
L	Characteristics length
b	Stretching rate constant
ϕ	Viscous dissipation
k_r	Chemical reaction parameter
V_0	Non zero positive constant

Original Article

INTRODUCTION

Sakiadis [1, 2] initiated the analysis of the boundary layer flow over a continuous solid surface moving with constant velocity. Sakiadas has taken the Classical Boundary layer problem in a different way which was mainly due to the fluid in the ambient. The surface is taken here is not extensible $\left(u_w = 0\right)$ whereas the physical situation concerned more with extensible surface ($u_w = cx$) moving in a cooling liquid. Crane [3] started the work of the boundary layer phenomena of an extensible surface where he considered the linear velocity of the surface which is at a certain distance from the slit.

Carragher and Crane [4], Vleggar [5] and Gupta and Gupta [6] analyzed flow and heat transfer from a stretching sheet to Newtonian fluid. An extension work was done by Chen and Char [7] to that of Gupta and Gupta to that of non-Newtonian which are abundantly used in many industrial engineering applications. Some important fluids which are frequently used in industries are visco elastic fluids, second grade fluids, power law fluids and etc. Because of this the analysis of boundary layer behavior has been further extended to non – Newtonian fluids.

Pillitsis and Beris [8] have done theoretical study of visco elastic fluid in an undulating tube which was similar to flow through porous media. Moreover, heat transport phenomena was neglected by the authors. Rafael cortell[9] have evaluated the effects of viscous dissipation work done due to deformation generation of internal heat/Absorption. Rafael cortell [10] analyzed Thermal radiation for the visco elastic fluid flow. The effect of viscous dissipation and thermal radiation over non linear stretching sheet has been discussed, with the exclusion of porous medium.

Abel et al [11] examined the visco-elastic non-Newtonian boundary layer flow of Walters liquid b past a stretching sheet, taking non-uniform heat source with frictional heating, into account. Also the effects of viscous and ohmic dissipation in MHD flow of visco elastic boundary layer flow were investigated by the same author. The influence of thermal radiation and non-uniform heat source on MHD flow of visco elastic fluid of Walter’s liquid B were described by Abel and Nandeppanavar [12].

In the above discussion porous medium is excluded, and the study of non-Newtonian fluid flow through porous medium got good significance as some particular polymer solutions attain sweep of better volumetric efficiency in oil displacement mechanism, while injecting into reservoirs which is of considerable importance. Abell and Venna[13] worked on the flow and heat transfer characteristics of visco elastic boundary layer flow in porous medium over a stretching surface. Abel et al[14] studied the flow of hydro magnetic visco elastic fluid and heat transfer over a non isothermal stretching sheet which was embedded in porous medium with uniform heat source. Mahantesh et al [15] discussed the role of viscous dissipation on the heat transfer of a second grade fluid through porous medium over a impermeable linear stretching sheet. Chandra Sekhar K. V [16] examined the MHD boundary layer flow and heat transfer towards an exponentially stretching sheet embedded in a thermally stratified medium subject to suction.

The above survey says that there is no analyses of heat transfer to visco elastic fluid flow in porous medium through impermeable stretching sheet under the influence of viscous dissipation with chemical reaction parameter in energy equation.

In the present paper the influence of chemical reaction parameter under the influence of different parameters are examined.

Mathematical Formulation of the Problem

We begin the present problem with, laminar two – dimensional flow of an incompressible, second grade fluid through a porous medium past a flat sheet coinciding with the plane y=0 and the flow being confined to y>0.

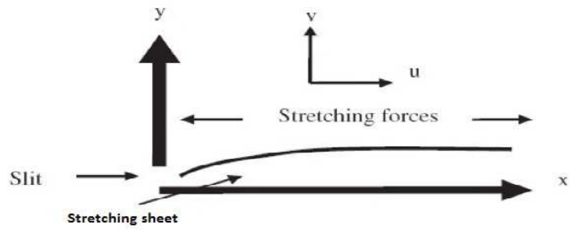

Figure 1: Schematic Diagram of the Physical Model

The flow is generated due to linear momentum of stretching of the sheet, caused by application of two equal forces simultaneously along the x – axis in opposite direction. Keeping the origin fixed, the sheet is then stretched with a speed varying linearly with distance from the slit. The x – axis has been taken along the surface, y – axis being normal to it and u, v are the tangential and normal velocities, of the fluid respectively. The governing equations of the problem are

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

$$\cdot u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}=\nu\frac{\partial^2 u}{\partial y^2}+k_0\left\{\frac{\partial}{\partial x}\left(u\frac{\partial^2 u}{\partial y^2}\right)+\frac{\partial u}{\partial y}\frac{\partial^2 v}{\partial y^2}+v\frac{\partial^3 u}{\partial y^3}\right\}-\frac{\nu}{k'}u \tag{2}$$

Here k_0 , ν and K' are elastic kinematic viscosity and permeability parameters of the medium respectively.

The conditions for the velocity fields at the boundary are given by,

$$u=bx, v=0, u\rightarrow 0 \, as \, y\rightarrow\infty \text{ at } y=0 \tag{3}$$

Where b is the constant of stretching rate. Introducing the new variables

$$u=bxf_\eta(\eta), v=-(b\nu)^{\frac{1}{2}}\, y, \eta=\left(\frac{b}{\nu}\right)^{\frac{1}{2}} y \tag{4}$$

Using the (4), equation (1) is trivially satisfied and equations (2) and (3) transformed as

$$f_\eta{}^2-ff_{\eta\eta}=f_{\eta\eta\eta}+k_1\left\{2f_\eta f_{\eta\eta}-ff_{\eta\eta\eta\eta}-f_{\eta\eta}{}^2\right\}-k_2 f_\eta-\frac{Mk_2\nu f_\eta}{k\rho} \tag{5}$$

$$\begin{aligned} &f_\eta=1,\; f(\eta)=0 \; at\,\eta=0 \\ &f_\eta(\eta)\rightarrow 0,\; f_{\eta\eta}\rightarrow 0\, as\,\eta\rightarrow\infty \end{aligned} \tag{6}$$

$k_1 = \dfrac{k_0 b}{\nu}$ is the second grade fluid parameter and $k_1 = \dfrac{\nu}{k' b}$ porosity parameter.

Now we discuss the heat transfer analysis in the following section.

Heat Transfer Analysis

The boundary layer heat transport equation in the presence of viscous dissipation, for the two – dimensional flow problem is given by

$$\rho c_p \left(u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} \right) = k \frac{\partial^2 T}{\partial y^2} + \phi - \frac{k_r'^2 \nu}{V_0^2} \tag{7}$$

Where, $$\phi = \mu \left[\left(\frac{u^2}{k'} \right) + \left(\frac{\partial u}{\partial y} \right)^2 \right], \; kr^2 = \frac{k_r'^2 \nu}{V_0^2} \tag{8}$$

The boundary conditions are given by

$$T = T_w = T_\infty + A \left(\frac{x}{l} \right)^2 \; at \; y = 0 \tag{9}$$

$$T \to T_\infty \quad as \; y \to \infty \tag{10}$$

Where T_w is the temperature of the sheet, T_∞ is the temperature of the fluid away from the sheet and l is the characteristic length.

Defining the non-dimensional temperature $$\theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty}, \tag{11}$$

Using (11), equation (7) can be redrafted in the form

$$\theta_{\eta\eta} + prf\theta_\eta - 2prf_\eta \theta = -Epr\left[k_2 f_\eta^2 + f_{\eta\eta}^2 \right] \tag{12}$$

Where $$pr = \left(\frac{\mu c_p}{k} \right), E = \left(\frac{b^2 l^2}{C_p A} \right) \tag{13}$$

Are the Prandtl and Eckret numbers

Consequently the boundary conditions (9) and (10) take the form

$$\begin{aligned} &\theta(\eta) = 1 \; at \; \eta = 0 \\ &\theta(\eta) \to 0 \; as \; \eta \to \infty \end{aligned} \tag{14}$$

RESULTS AND DISCUSSIONS

Influence of chemical reaction parameter on temperature profiles in presence of second grade fluid parameter, Porosity parameter, Prandtl number and Eckret number have been examined. Figures,2 3, 4,5 depicts that increase of chemical reaction parameter leads to increase of temperature profiles in presence or absence of Eckert number, second grade fluid parameter Porosity parameter, and Prandtl number.

CONCLUSIONS

- For individual values of Chemical reaction parameter (kr), it has been noticed that the temperature increases near the slit up to some extent and decreases gradually as moving away from the slit.
- It is observed that far away from the slit the influence of the chemical reaction parameter is not up to the mark.
- It is noticed that the more the increase of chemical reaction parameter, the more the temperature

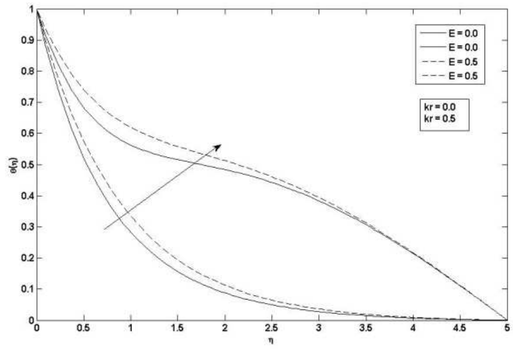

Figure 2: Effect of Chemical Reaction Parameter on Temperature Profiles Wrt to Eckert Number Ec

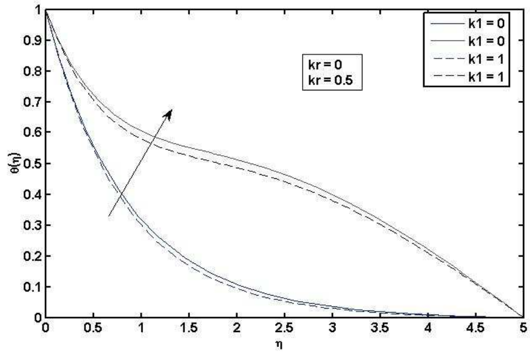

Figure 3: Influence of Chemical Reaction Parameter on Temperature Profiles Wrt to Second Grade Fluid Parameter K_1

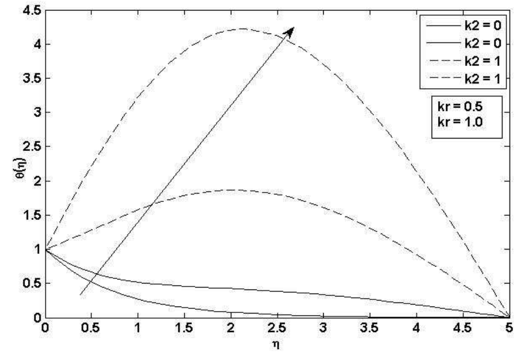

Figure 4: Variation of Temperature Profiles Under the Influence of Chemical Reaction Parameter Temperature Profiles in Presence Porosity Parameter

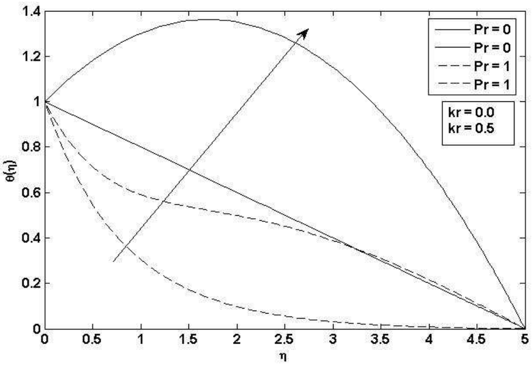

Figure 5: Chemical Reaction Parameter Effect on Temperature Profiles Wrt to Prandtl Number

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